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DRAWINGS ATTACHED

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(19) THE PATENT OFFICE LONDON

(54) ELECTROMECHANICAL TRANSDUCER

(71) We, K.G. LUKE ENGINEERING PROPRIETARY LIMITED, of Cook Street, Mitcham, in the State of Victoria, Commonwealth of Australia,

do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to electromechanical transducers. It has particular, but not exclusive, application to ultrasonic transducers for industrial processes in which ultrasonic energy is imparted into a fluid, as may be the case in ultrasonic cleaning, the homogenization of fluids and the disintegration of suspensions such as bacterial cultures.

Ultrasonic transducers of the electromechanical type convert high frequency electric oscillations into ultrasonic vibrations by the use of piezoelectric or magnetostrictive effects. One such transducer which is commonly used to impart vibrations into ultrasonic cleaning tanks is of a composite construction comprising a piezoelectric or electrostrictive drive element sandwiched between a pair of bodies which are not piezoelectric or electrostrictive. The two bodies may be bonded to the drive element and, on installation, one of the bodies is bonded or otherwise attached to the load to be vibrated, for example an ultrasonic cleaning tank. A preload compressive stress may be applied to the drive element and the bonds between that element and the two bodies by a preloading means such as one or more high tensile bolts which can be tightened to draw the two bodies toward one another. It is found that higher activity is obtained if the body which is to be attached to the load is less dense than the other body. For example, it may be constructed of aluminium and the other body of steel. By the present invention, the performance of such a transducer can be further improved by constructing the less dense body to a novel shape. As will become clear from the actual test results discussed below, the shaping of the less dense body in accordance with the present invention not only enables a higher activity or output to be obtained but a most desirable consistency of output over a broad range of frequencies.

According to the invention an ultrasonic electro-mechanical transducer comprises a drive element composed of at least one disc of a piezoelectric or electrostrictive material; a metallic ultrasonic energy transmitting body disposed to one side of the drive element; a metallic mass loading body of greater density than the energy transmitting body disposed to the other side of the drive element; and a central clamping bolt having a stem received by aligned central bores in the mass loading body, the drive element and the energy transmitting body and centrally clamping the energy transmitting body and the mass loading body together to hold the drive element between them in axial compression; wherein the energy transmitting body is, apart from its central bore, uniformly solid to closely surround the bolt stem, it has a circular drive element end of one diameter and a circular end of a greater diameter remote from the drive element end and it progressively increases in diameter from its drive element end toward its remote end to define an external peripheral surface of revolution which in axial cross section of the body is curved.

In one embodiment of the invention the rate of increase of diameter of said surface of revolution increases in the direction toward the remote end of the energy-transmitting body. The surface of revolution may, for example, have a curvature which, in axial cross-section of the body, is generally of the nature of hyperboli or exponential outwardly concave curvature. The energy-transmitting body may also comprise a right circular cylindrical portion at said remote end thereof, the junction of said peripheral surface of revolution and the right-circular cylindrical surface of that portion being sharply defined,

In another embodiment of the invention, the rate of increase of diameter of said surface of revolution decreases in the direction toward the remote end of the energy-transmitting body.

The invention will now be described in more detail with the aid of the accompanying drawings.

In the drawings,

Figures 1 to 4 illustrate known types of ultrasonic transducers;

Figures 5 and 6 illustrate two alternative ultrasonic transducers constructed in accordance with the present invention;

Figure 7 is a graph which shows the relative activities of the four prior art transducers over a broad frequency range;

Figure 8 shows the activity of the transducer of Figure 5 when working against two different loads;

Figure 9 shows results of further tests conducted with the transducer of Figure 5; and

Figures 10 and 11 show results of tests conducted with the transducer of Figure 6.

The four transducers of Figures 1 to 4 are labelled A, B, C and D respectively. They are known forms of composite transducers. Each has a drive element 11 consisting of two polarized piezoelectric ceramic wafers (lead zirconate titanate) sandwiched between a relatively dense steel body 12 and a less dense aluminium alloy body 13. The drive element is bonded to the bodies 12, 13 and a preload compressive stress is applied by biasing means 14. In the transducers of Figures 1, 3 and 4 the biasing means is comprised of a single high tensile bolt disposed centrally of the transducer whereas the arrangement shown in Figure 2 has a plurality of circumferentially spaced preloading bolts. In each case electrical oscillations are applied between a thin plate 16 and the two polarized piezoelectric ceramic wafers.

The transducer E of Figure 5 is also of the composite type. It comprises a drive element 15 in the form of a pair of polarized piezoelectric ceramic wafers 17 disposed to either side of a thin conductive plate 18 and sandwiched between a steel body 19 and an aluminium alloy body 21. The drive element may be bonded to the bodies 19, 21 and a preload compressive stress is applied by a high tensile cap screw 22 extending down through body 19 and a central opening in the drive element to screw into a tapped bore in body 21.

The body 21 of the transducer E is shaped in accordance with the present invention. Figure 5 is drawn to scale. The drive element end 23 has a diameter of 1-1/2″ whereas its end 24 remote from the drive element has a diameter of 2-1/4″. The body progressively increases in diameter from its end 23 toward end 24 so that there is defined a peripheral surface of revolution 26 all points on which must lie on or outside the diameter of the end 23. It will be seen that the rate of increase of diameter increases in the direction toward the end 24 so that, in axial cross-section of the body, the surface 26 has outwardly concave curvature. In fact in this particular case the curvature is substantially hyperbolic.

The body 21 comprises a short right circular cylindrical portion 27 at the end remote from the drive element and the junction of the peripheral surface 26 with the peripheral surface of the portion 27 is sharply defined at 28, i.e. the two meet at a sharp corner or crest. In the illustrated construction the total length of the body 21 is 1-3/8″ and right circular cylindrical portion 27 is only 1/16″ long. The length of portion 27 is not particularly critical but it is important for best results that the intersection of this portion with the outwardly curving surface of revolution be as sharp as possible.

Figure 7 shows the relative effectiveness of the four prior art transducers in imparting ultrasonic vibrations into liquid in a tank. Normally a number of transducers would be bonded to the underside of the tank floor. However for this purpose only one transducer was fitted to the tank and the tank was filled with a 1:40 "Teepol" (trade mark) in water solution to a depth of 8-1/2″. The activity of each transducer was measured as an electrical output from a piezoelectric probe inserted into the liquid. The electrical output so obtained is plotted against the frequency of the input electrical signal.

Figure 8 shows comparable results obtained with the transducer of Figure 5. It will be seen that transducer E not only has a substantially higher relative activity but it provides for much "flatter" response. That is to say that the transducer will operate at a consistently high peak of performance over a broad range of frequencies. Since the prior art transducers perform best at one or two set frequencies it has in the past been necessary to carefully match the transducers to be fitted to any particular tank and to carefully "tune" the input generator. Because of the flatter response of the transducer in accordance with the present invention such critical "tuning" is not necessary. It will be appreciated that this improvement in performance is indeed most valuable. The reasons for the improvement in performance are not fully understood. Attempts to provide an emplanation by mathematical analysis have not been successful and in fact the performance of this transducer appears to be quite counter to any predictions based on currently accepted principles of ultrasonic wave transmission theory.

A further problem encountered with the prior art transducers has been that the depth of liquid in the tank has been most critical and that if the liquid level has not been set

accurately the ultrasonic activity is very much reduced. The two curves plotted on Figure 8 show a very much reduced variation in activity due to changes in liquid level. The results plotted on Figure 9 show that the transducer E provides a relatively "flat" response over a wide frequency range when used with a variety of solvents namely methylene chloride, trichloroethylene, CHLOROTHENE (trade mark) and FREON (trade mark), the one exception being methylene chloride.

Figure 6 shows an alternative transducer F also constructed in accordance with the present invention. It is very similar to the transducer E of Figure 5 and its like parts have been identified by the same numerals. In fact the only difference between the two transducers is in the shape of the surface of revolution 26 of the aluminium body 21. In transducer F the rate of increase of diameter of surface 26 decreases in the direction toward the end 24 so that, in axial cross-section of the body 21, the surface 26 has outwardly convex curvature. Figures 10 and 11 show the performance of transducer F under the same test conditions as carried out on the previous transducers. It will be seen that this transducer also provides a performance superior to that of the prior art constructions.

WHAT WE CLAIM IS:—

1. An ultrasonic electro-mechanical transducer comprising a drive element composed of at least one disc of a piezoelectric or electrostrictive material; a metallic ultrasonic energy transmitting body disposed to one side of the drive element; a metallic mass loading body of greater density than the energy transmitting body disposed to the other side of the drive element; and a central clamping bolt having a stem received by aligned central bores in the mass loading body, the drive element and the energy transmitting body and centrally clamping the energy transmitting body and the mass loading body together to hold the drive element between them in axial compression; wherein the energy transmitting body is, apart from its central bore, uniformly solid to closely surround the bolt stem, it has a circular drive element end of one diameter and a circular end of a greater diameter remote from the drive element end and it progressively increases in diameter from its drive element end toward its remote end to define an external peripheral surface of revolution which in axial cross section of the body is curved.

2. An ultrasonic electro-mechanical transducer as claimed in claim 1, wherein the central bore of said energy transmitting body is internally screw threaded and the stem of the clamping bolt is screwed into it to provide the respective clamping force.

3. An ultrasonic electro-mechanical transducer as claimed in claim 2, wherein the central bore of said energy transmitting body is a blind bore extending only partly through it from its drive element end.

4. An ultrasonic electro-mechanical transducer as claimed in any one of the preceding claims, wherein the drive element and the mass loading body both closely surrounded the stem of the clamping bolt.

5. An ultrasonic electro-mechanical transducer as claimed in any one of the preceding claims, wherein the rate of increase of diameter of said surface of revolution increases in the direction toward the remote end of said energy transmitting body.

6. An ultrasonic electro-mechanical transducer as claimed in claim 5, wherein the surface of revolution is, in axial cross-section of the body, generally of hyperbolic, outwardly concave curvature.

7. An ultrasonic electro-mechanical transducer as claimed in claim 5 or claim 6, wherein said transmitting body comprises a right circular cylindrical portion at said remote end thereof and the junction of said peripheral surface of revolution and the cylindrical surface of that portion is sharply defined.

8. An ultrasonic electro-mechanical transducer as claimed in claim 1, 2 or 3, wherein the rate of increase of diameter of said surface of revolution decreases in the direction toward the remote end of said transmitting body.

9. An ultrasonic electro-mechanical transducer as claimed in any one of the preceding claims, wherein the energy transmitting body is constructed of aluminium and the mass loading body is constructed of steel.

10. An ultrasonic electro-mechanical transducer, substantially as hereinbefore described with reference to and as illustrated in Figure 5 or Figure 6 of the accompanying drawings.

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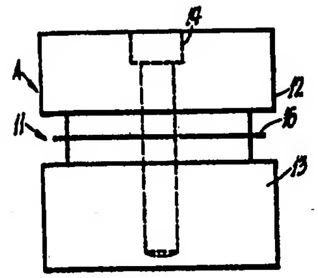

Fig. 1.

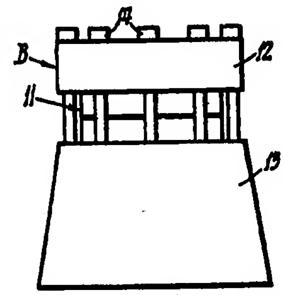

Fig. 2.

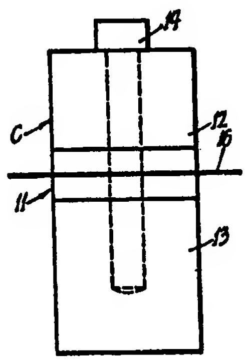

Fig. 3.

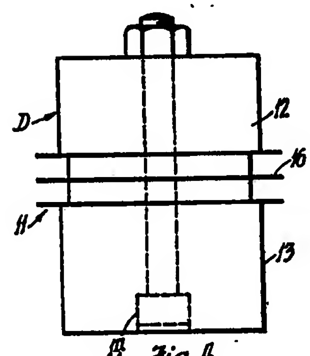

Fig. 4.

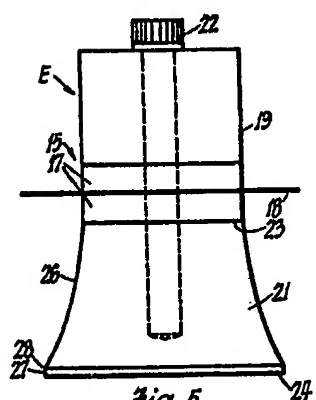

Fig. 5.

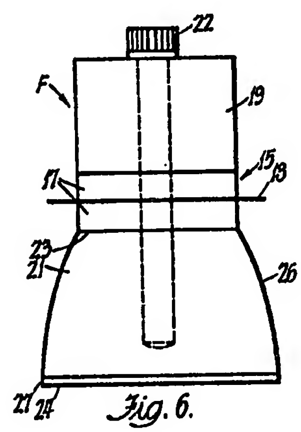

Fig. 6.

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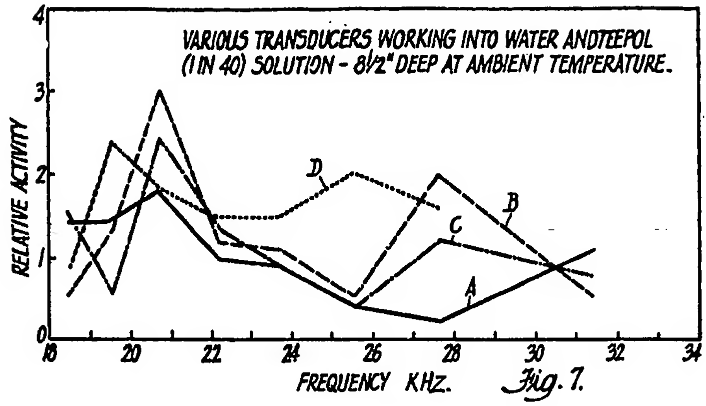

Fig. 7.

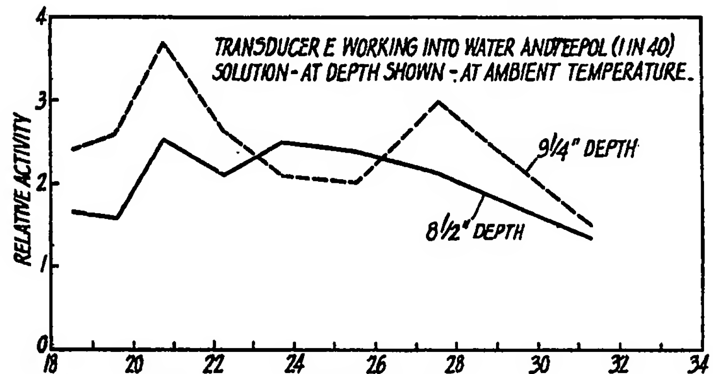

Fig. 8.

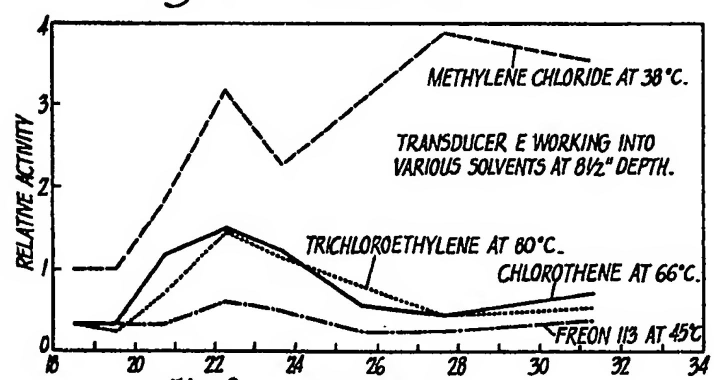

Fig. 9.

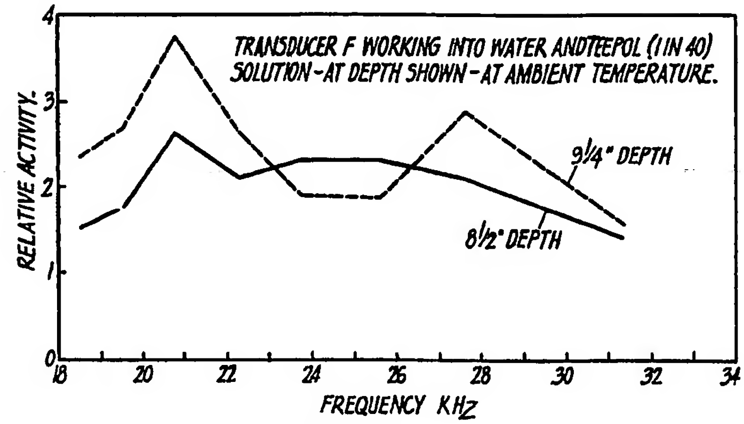

Fig. 10.

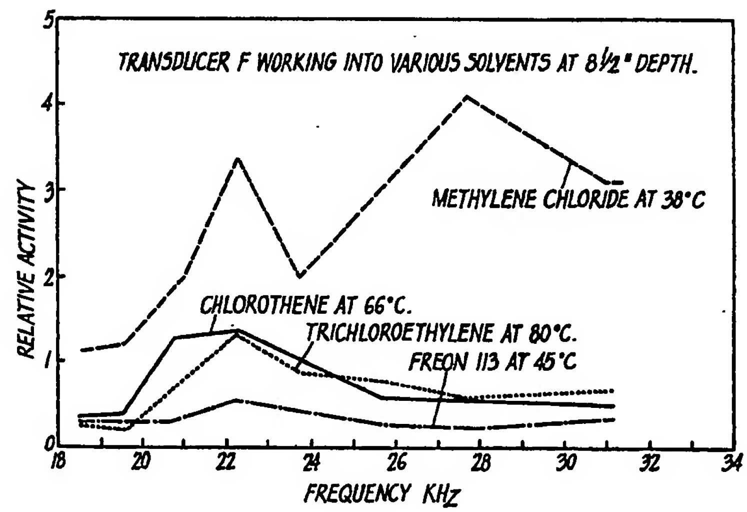

Fig. 11.

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